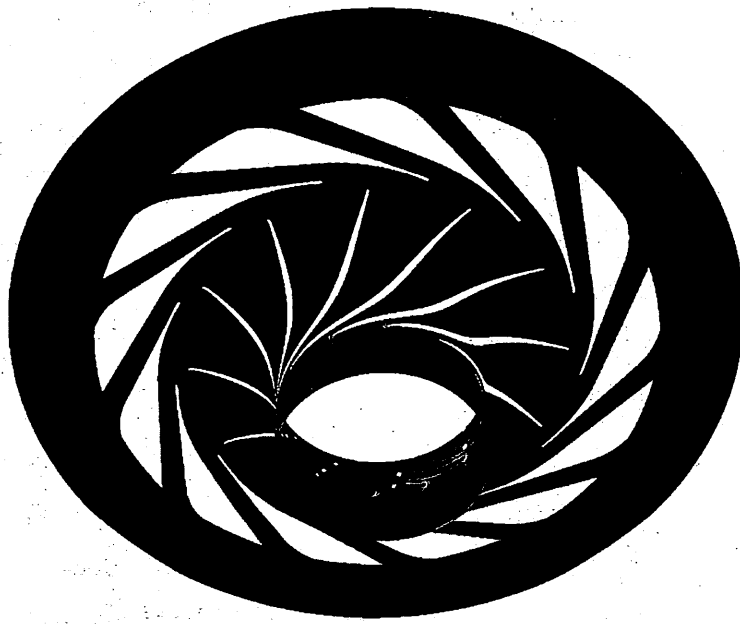




The CORSAIR Turbomachinery Code: Status and Plans



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Office of Information Technology**



Overview

- **Corsair algorithms**
- **Code capabilities**
- **Sample test cases**
- **Future plans**
- **Code validation (partial list)**



CORSAIR Algorithms - I

- **Time-dependent equations of motion**
 - Full Navier-Stokes, thin-layer Navier-Stokes or Euler
 - Variable fluid properties (C_p , γ) as a function of P , T
- **Third-order spatial discretization of inviscid fluxes**
 - Roe
- **Second-order spatial discretization of viscous fluxes**
 - Standard central differences
- **Second-order temporal accuracy**
- **Multi-block O-H grid topology**
 - O-grids around airfoils and in tip clearance regions
 - H-grids for remainder of flow field and nozzles
 - Well-suited for parallel simulations



CORSAIR Algorithms - II

- **Turbulence models**
 - Highly-modified Baldwin-Lomax model
- **Transition models**
 - Abu-Ghannam and Shaw
 - Mayle
 - Roberts
- **Boundary conditions**
 - Steady and unsteady inlet and exit
 - Specified wall temperature or heat flux
 - Film cooling/mass injection
 - Symmetry, part-span shrouds
 - Actuator disk
 - Component linking
- **Grid Motion**
 - Arbitrary translation/rotation
 - Blade vibration



CORSAIR Algorithms - III

- **Parallel simulations**
 - MPI used for coarse-grain decomposition
 - decomposition by blade row or passage
 - decomposition by O- and H-grids
 - decomposition by component
 - user specified decomposition
 - OpenMP used for fine-grain decomposition
- **Graphical User Interface**
 - Grid generation and flow solver
 - Error checking and user's manual/help facility
 - Post-processing



CORSAIR Algorithms - IV

- **Miscellaneous capabilities**
 - Conjugate heat transfer capability
 - Provides unsteady pressure file for stress analysis
 - Comprehensive design page
 - Provide Fourier decomposition of unsteady pressures
 - Will run on any Unix, Linux or Windows NT platform

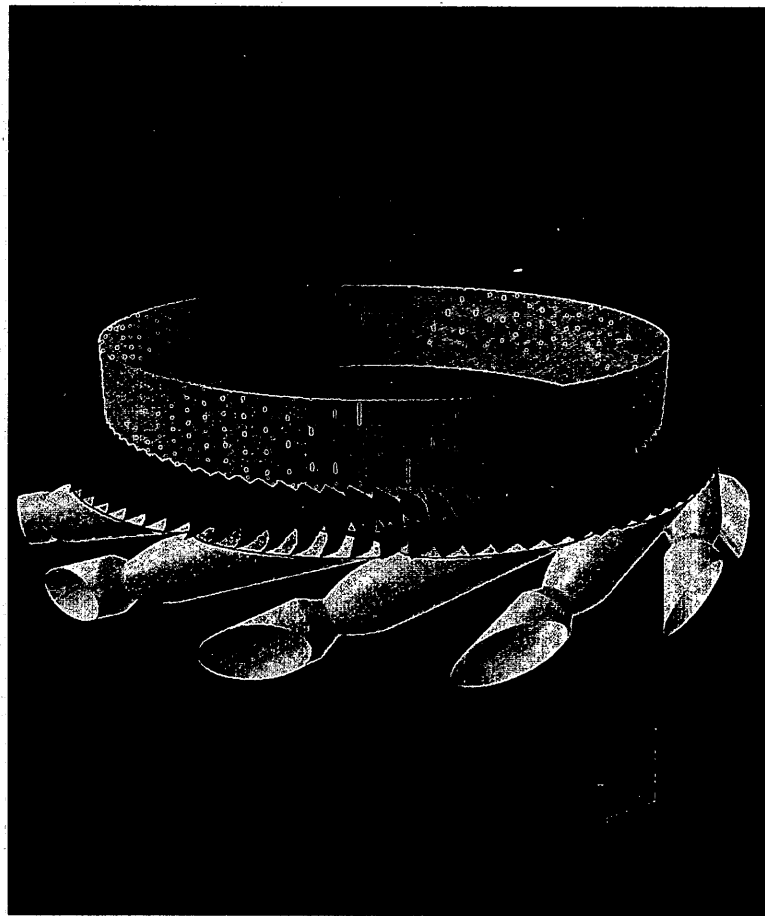


Full- and Partial-Admission Turbine Simulations

- **Objective - determine the effects of partial admission on the rotor unsteady load and performance as a function of circumferential location**
- **Simplex supersonic turbine**
 - Straight centerline nozzles
- **Full-Admission simulation**
 - 1 nozzle and 8 rotors modeled
 - 10 global cycles
- **Partial-Admission simulation**
 - 6 nozzles and 95 rotors modeled
 - 1+ revolutions



Simplex Turbine





Instantaneous Mach Number - I



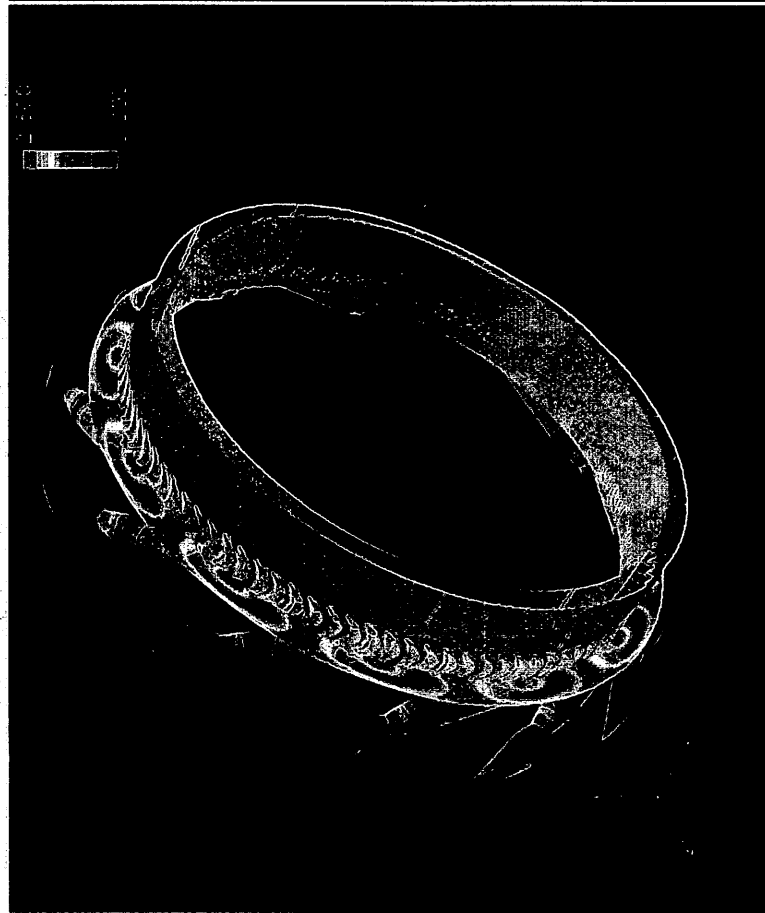
FULL ADMISSION



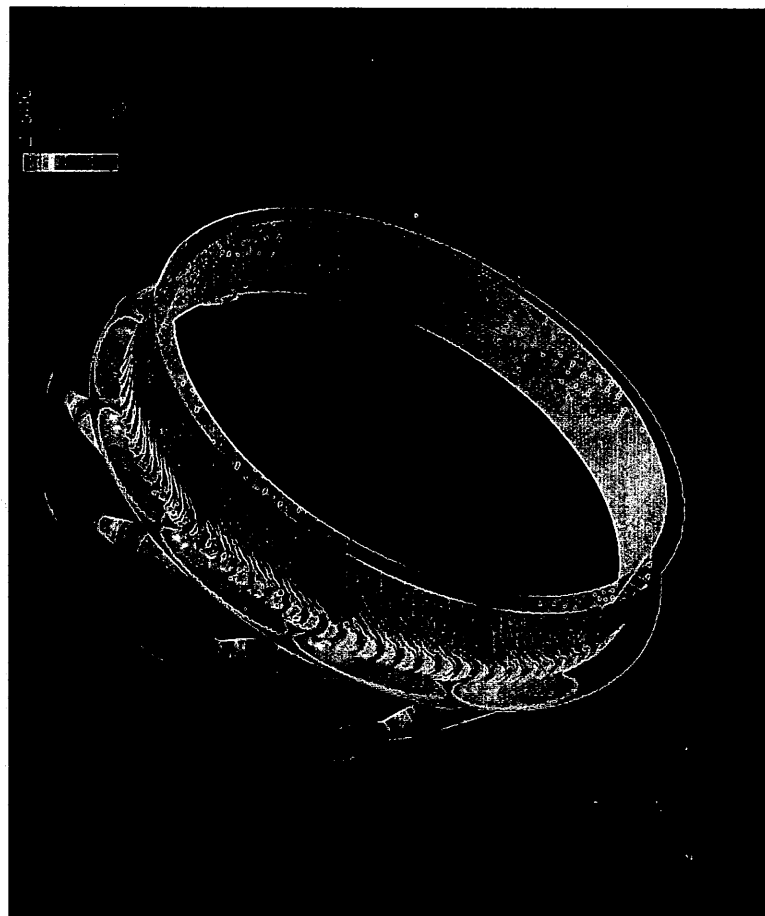
PARTIAL ADMISSION



Instantaneous Mach Number - II



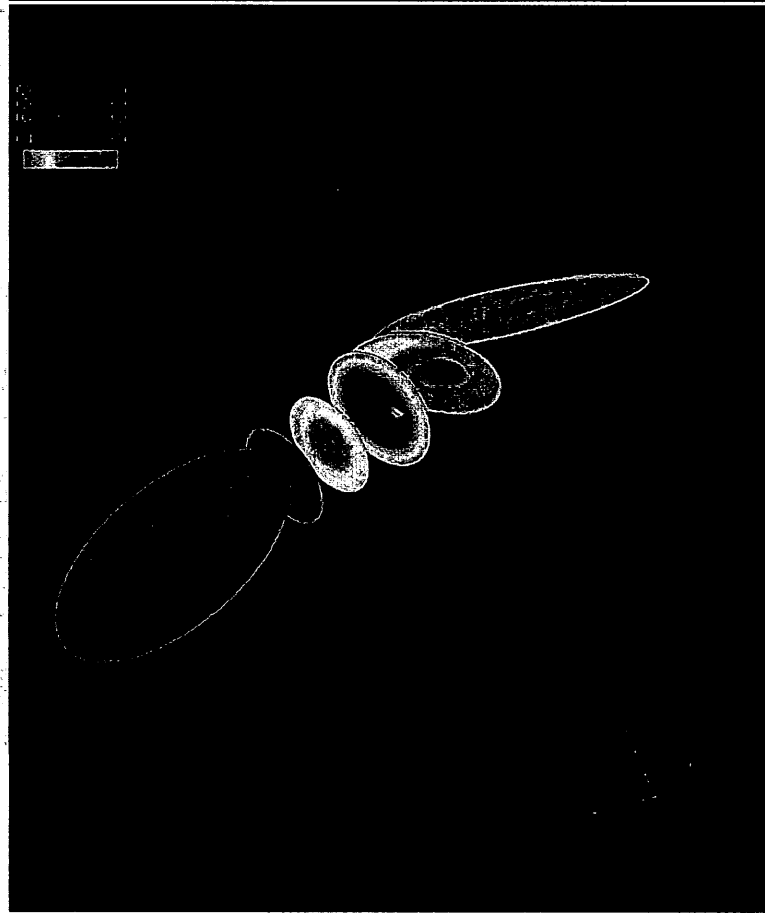
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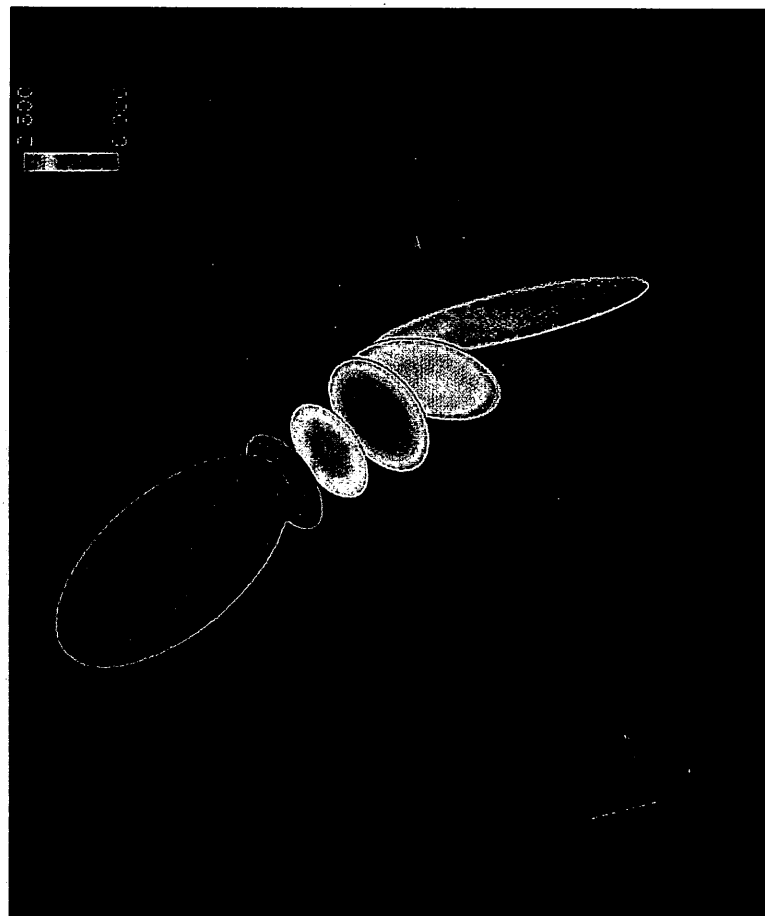
PARTIAL ADMISSION



Instantaneous Nozzle Mach Number



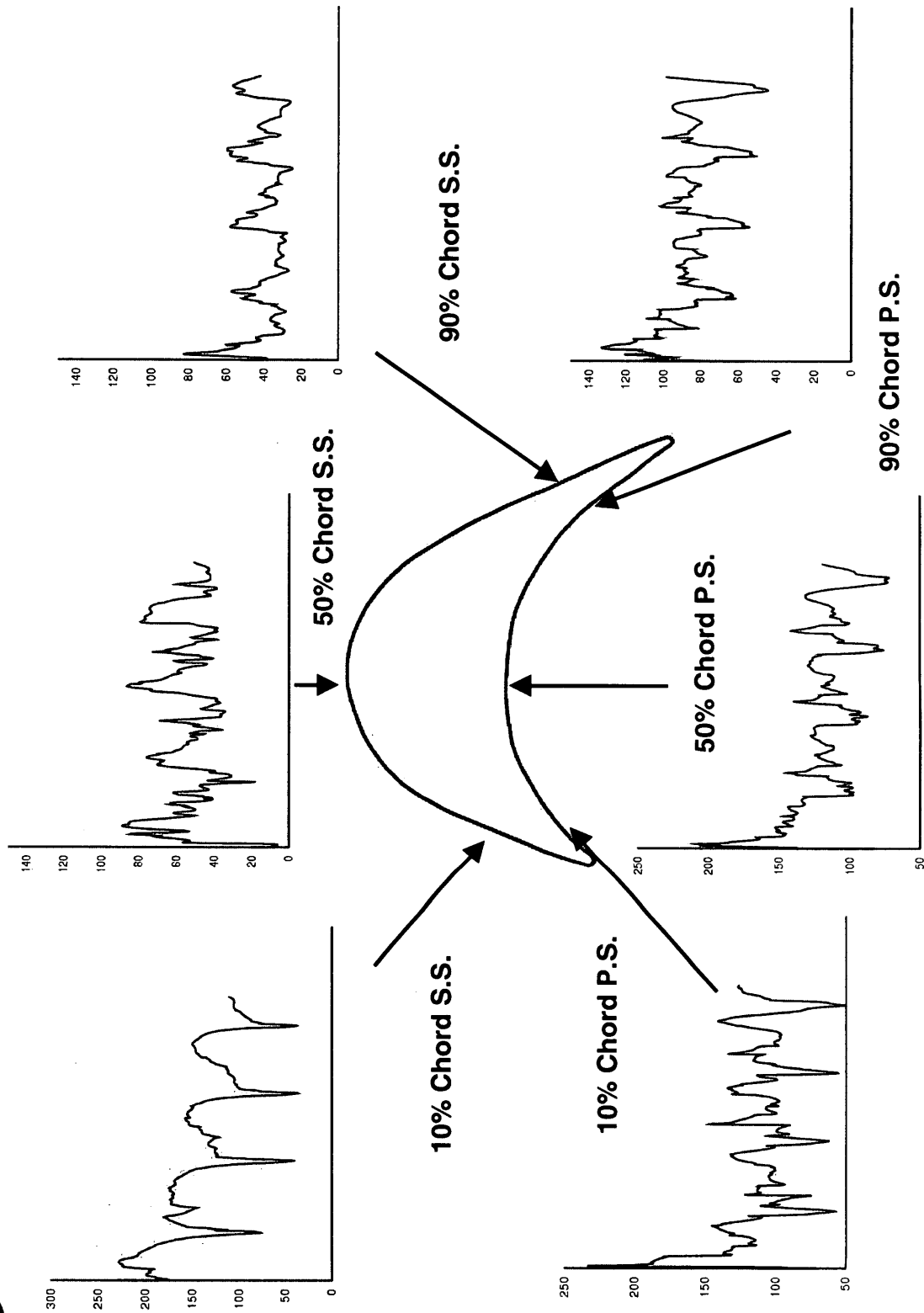
FULL ADMISSION



PARTIAL ADMISSION

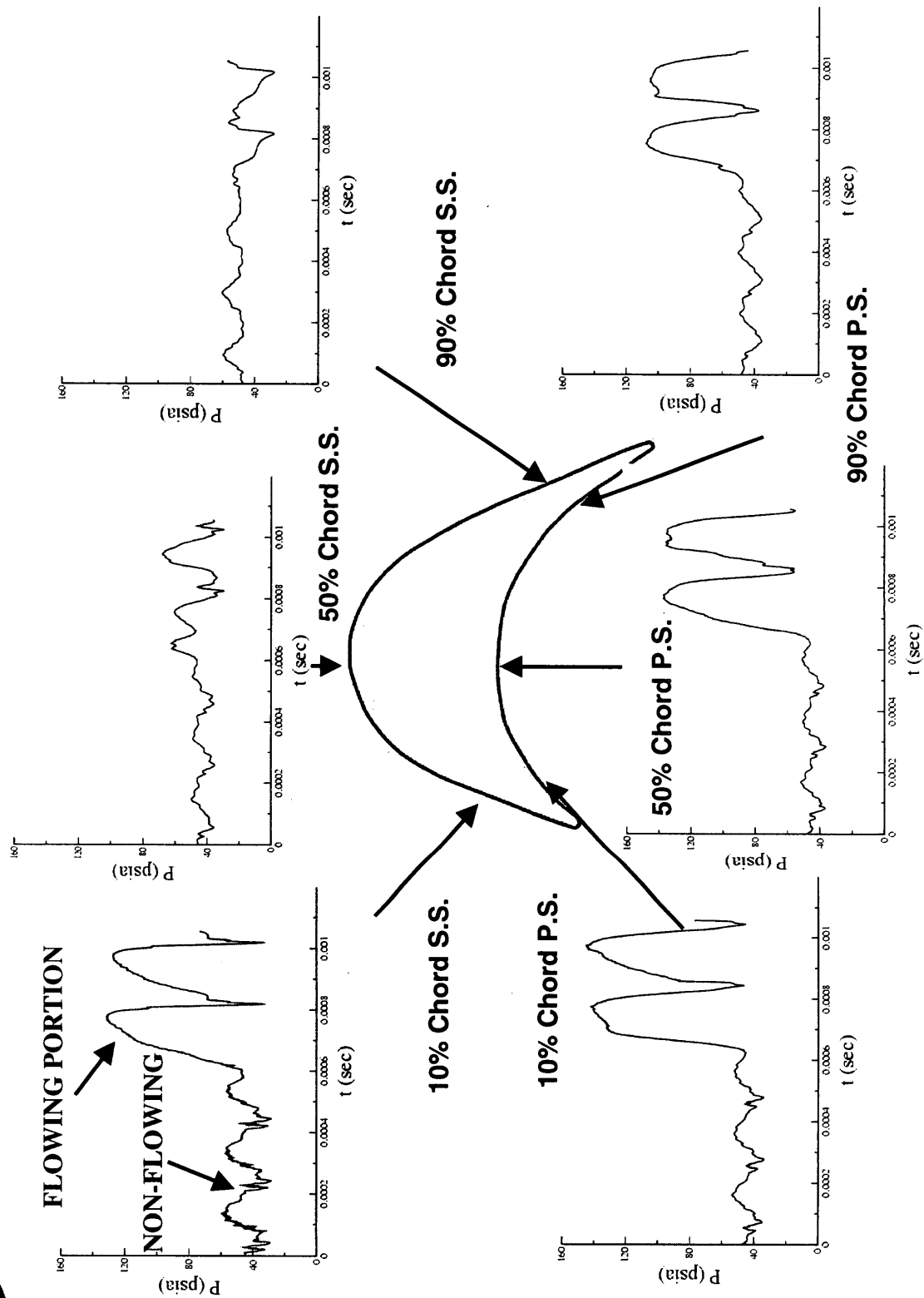


Unsteady Pressure – Full Admission – 50% Span



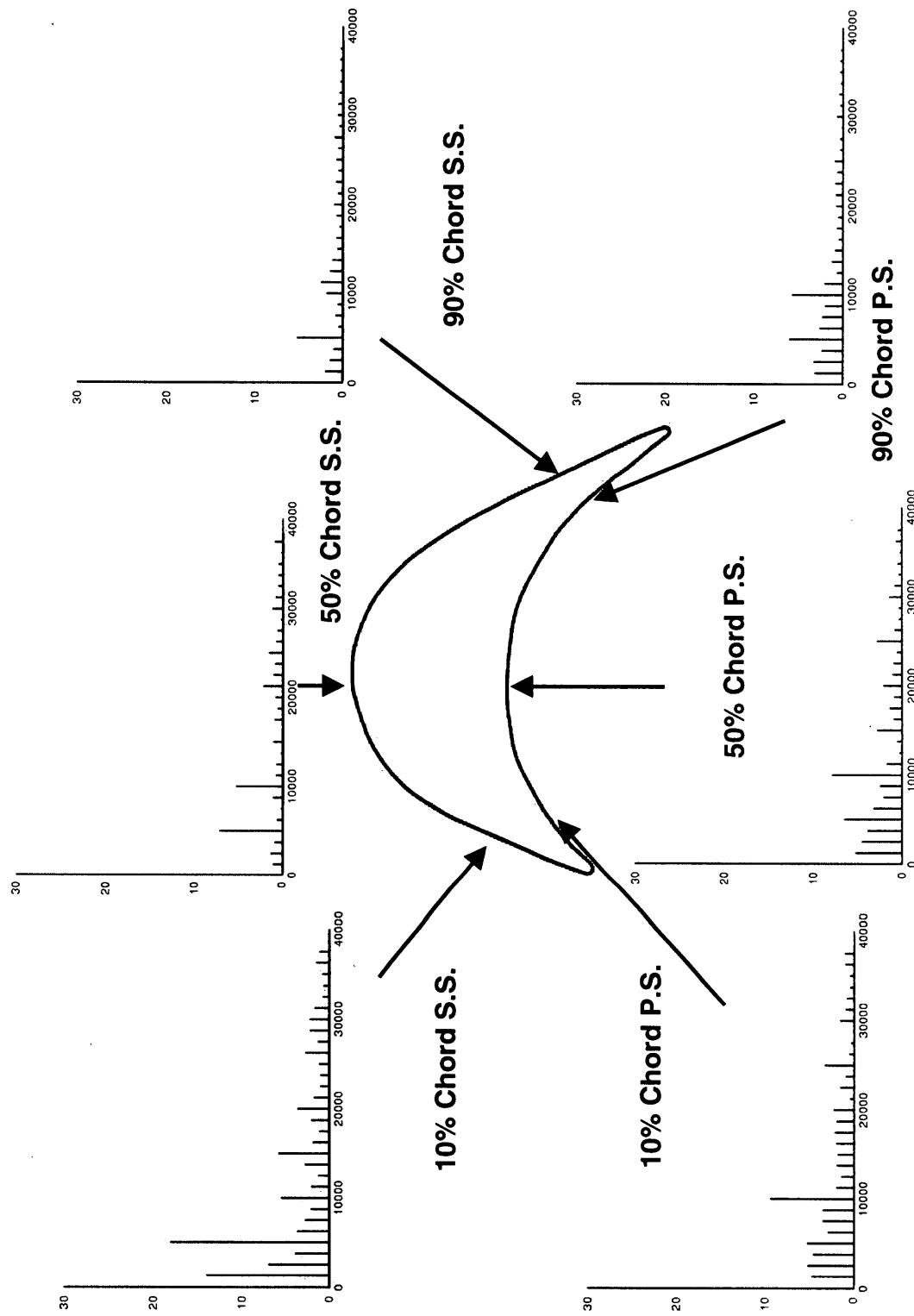


Unsteady Pressure – Partial Admission – 50% Span



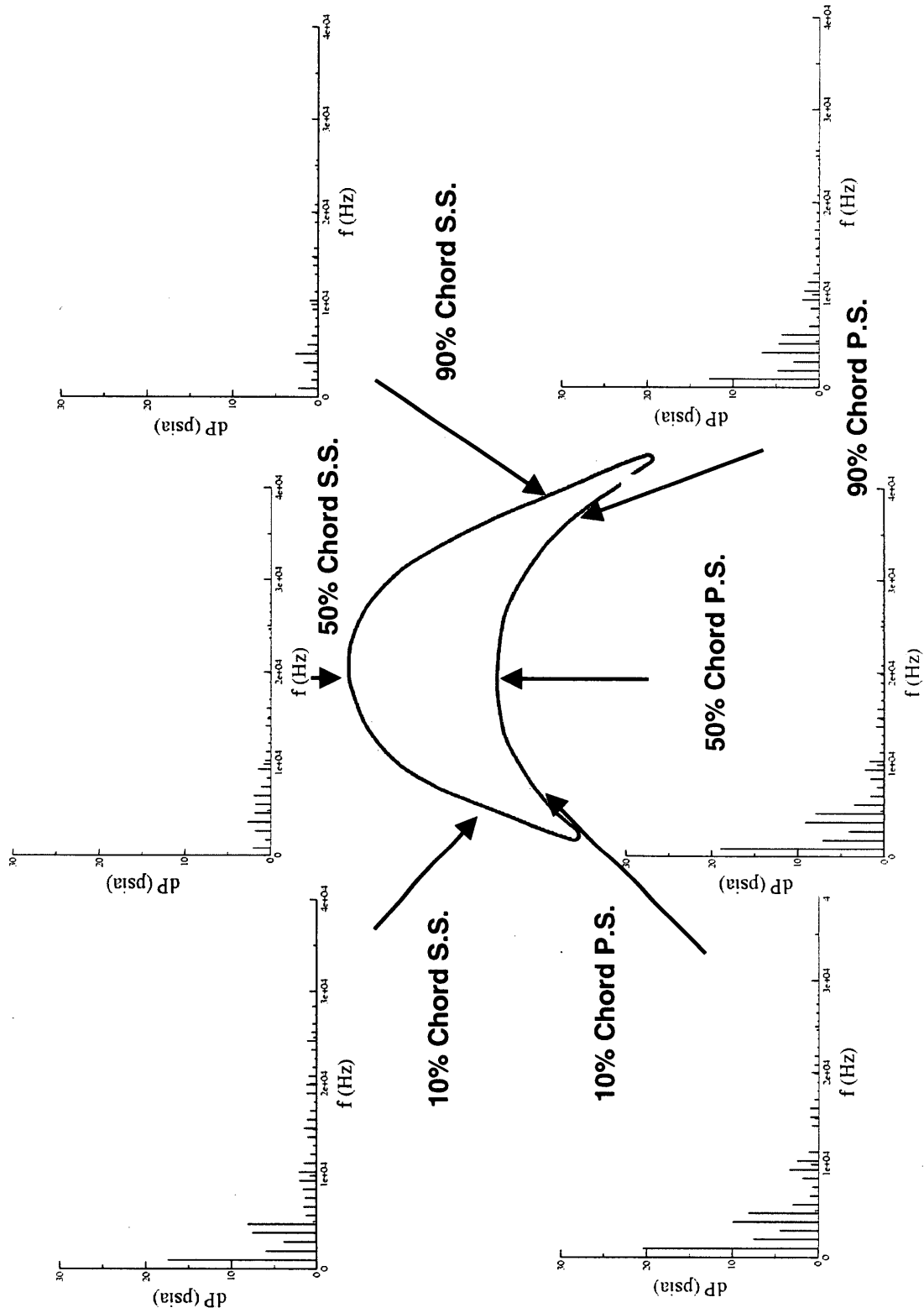


Pressure Decomp – Full Admission – 50% Span



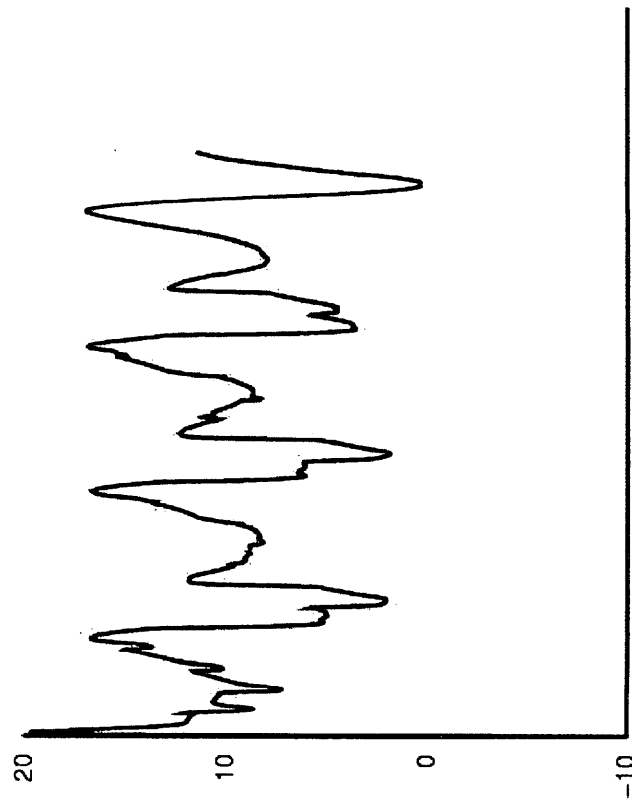


Pressure Decomp – Partial Admission – 50% Span

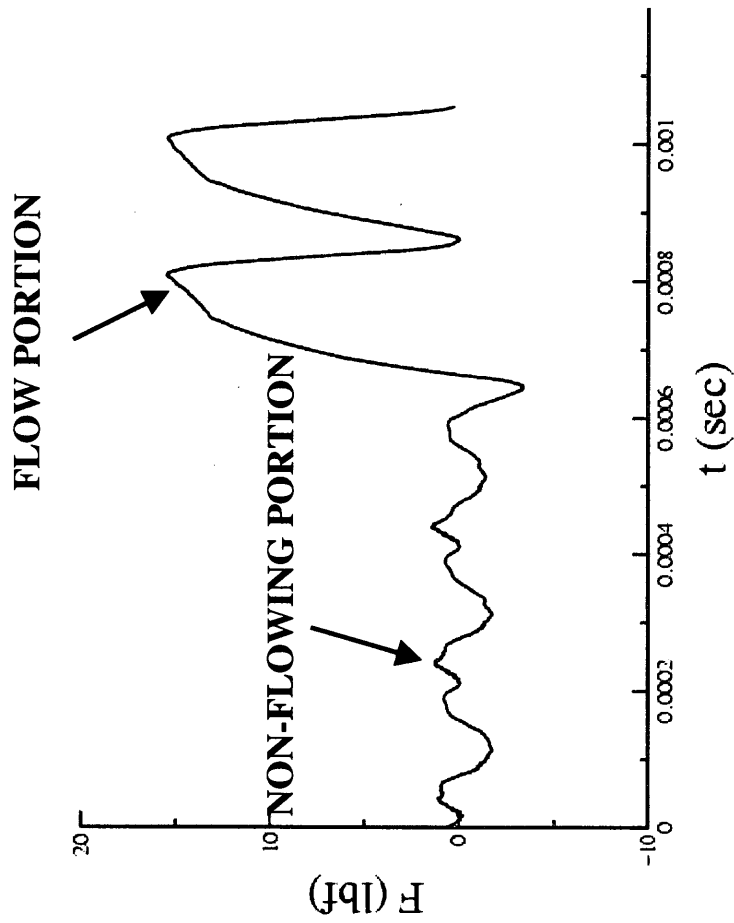




Unsteady Integrated Tangential Force



FULL ADMISSION



PARTIAL ADMISSION

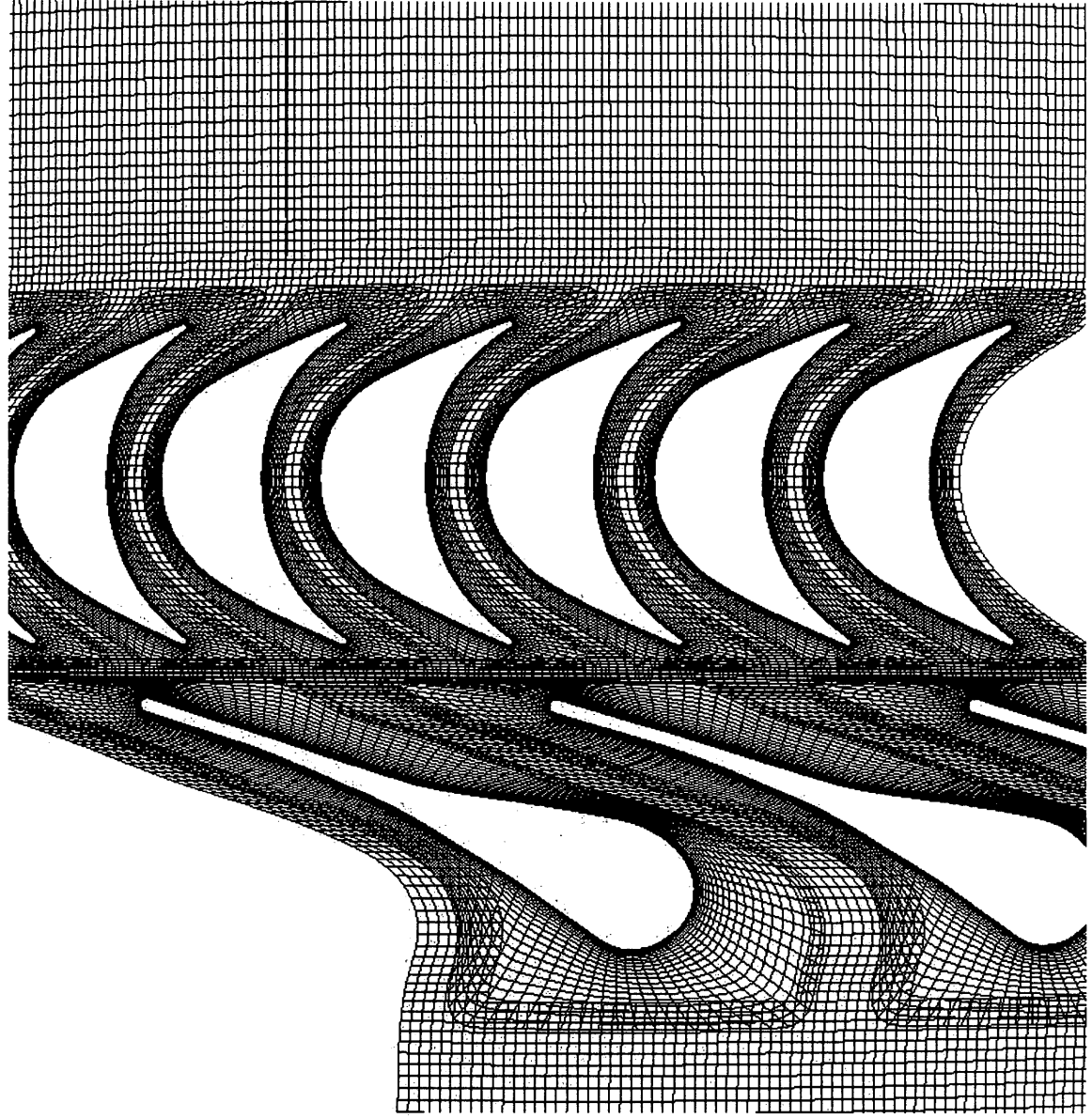


Variable Fluid Property RLV-133 Simulations

- **Objective - determine the differences in loadings and performance predicted with constant and variable fluid property simulations**
- **Cp and gamma varies as a function of temperature and pressure**
 - equations for JP, RP, kerosene, oxygen and hydrogen
- **Constant fluid property simulation**
 - 2-nozzle/5-rotor simulation
 - 8 full cycles completed
- **Variable fluid property simulation**
 - 2-nozzle/5-rotor simulation
 - 8 full cycles completed

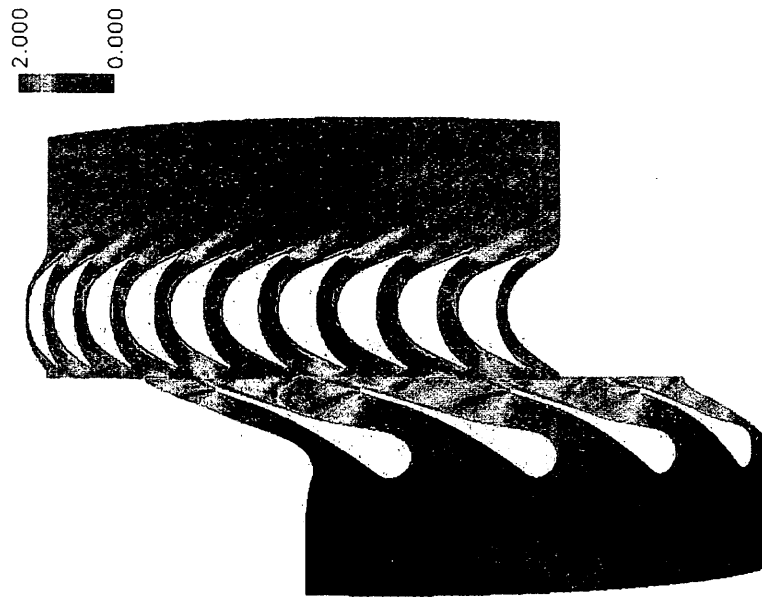


Computational Grid

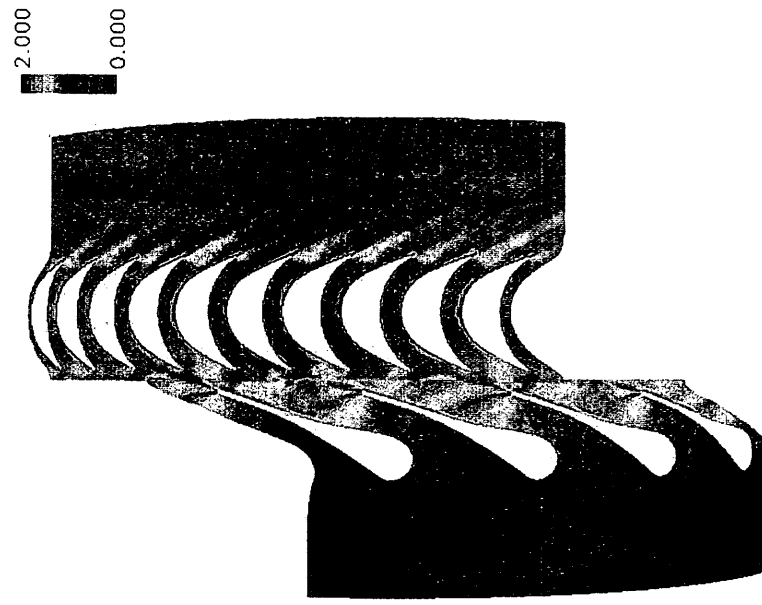




Instantaneous Mach Number - Midspan



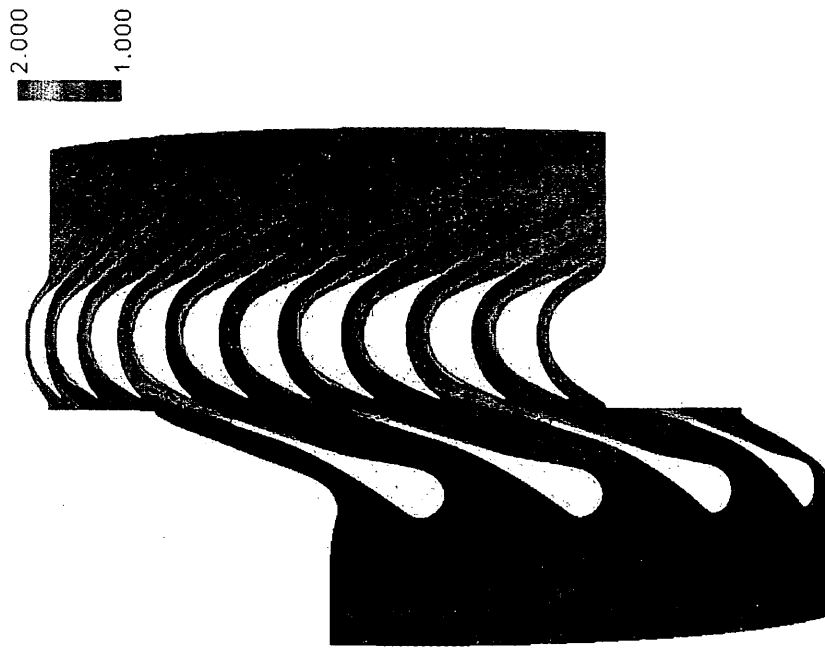
CONSTANT FLUID PROPERTIES



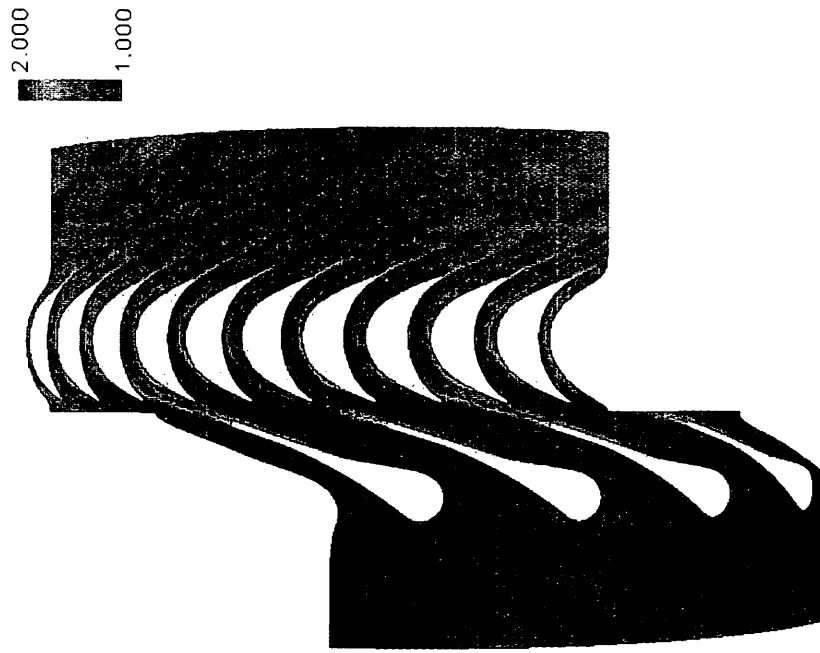
VARIABLE FLUID PROPERTIES



Instantaneous Entropy Function - Midspan



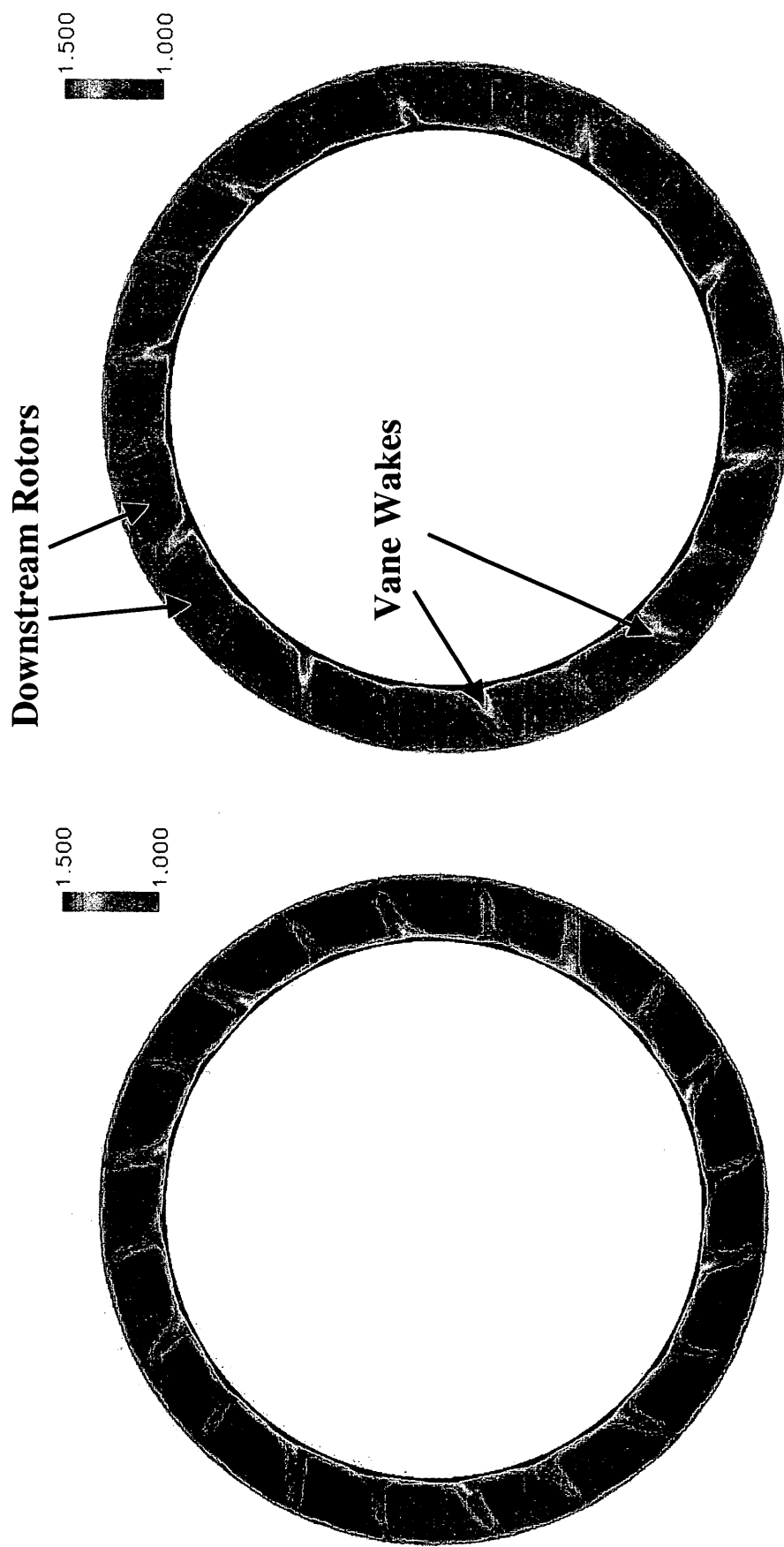
CONSTANT FLUID PROPERTIES



VARIABLE FLUID PROPERTIES



Instantaneous Entropy Function - Vane Exit

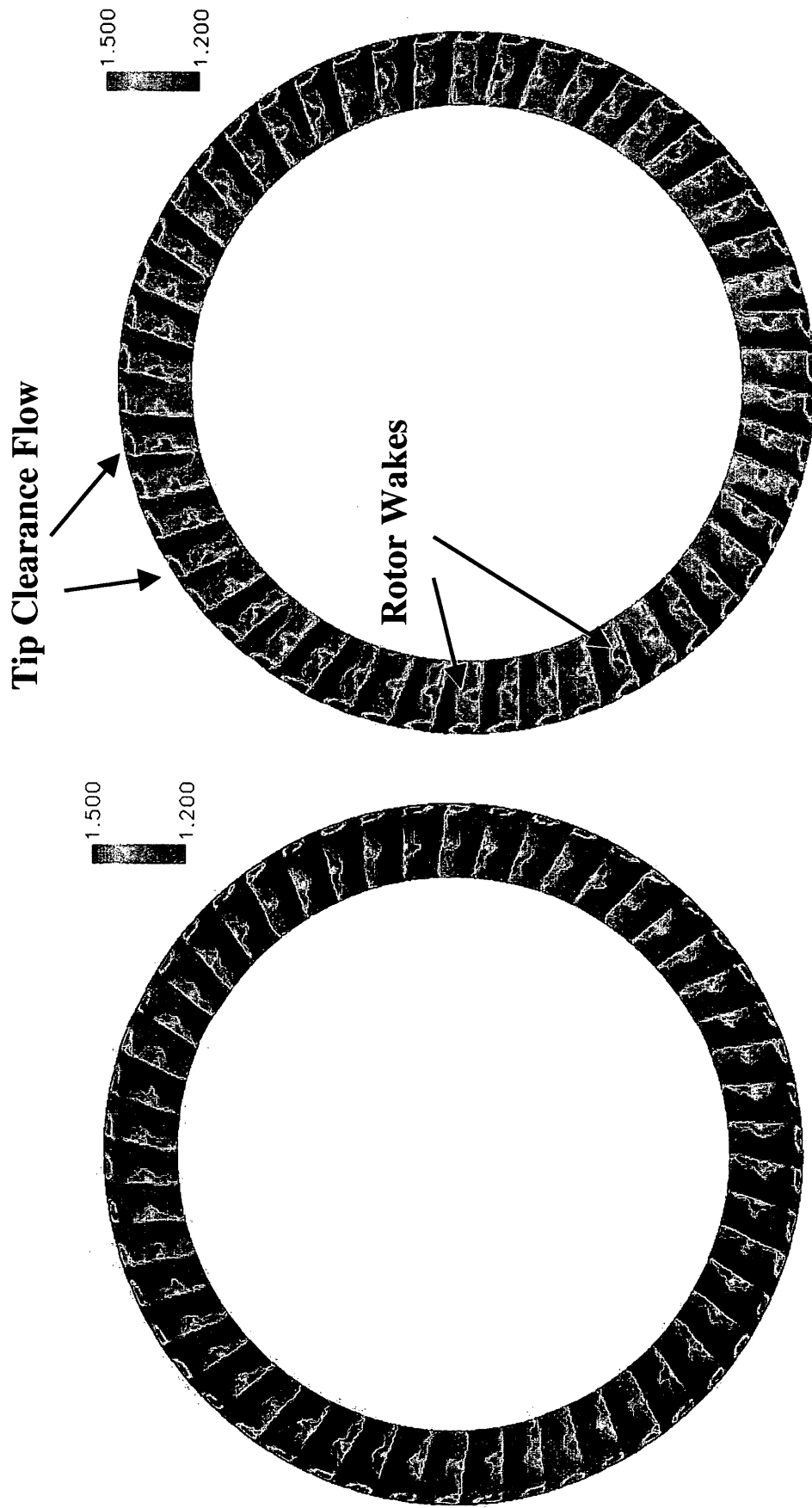


CONSTANT FLUID PROPERTIES

VARIABLE FLUID PROPERTIES



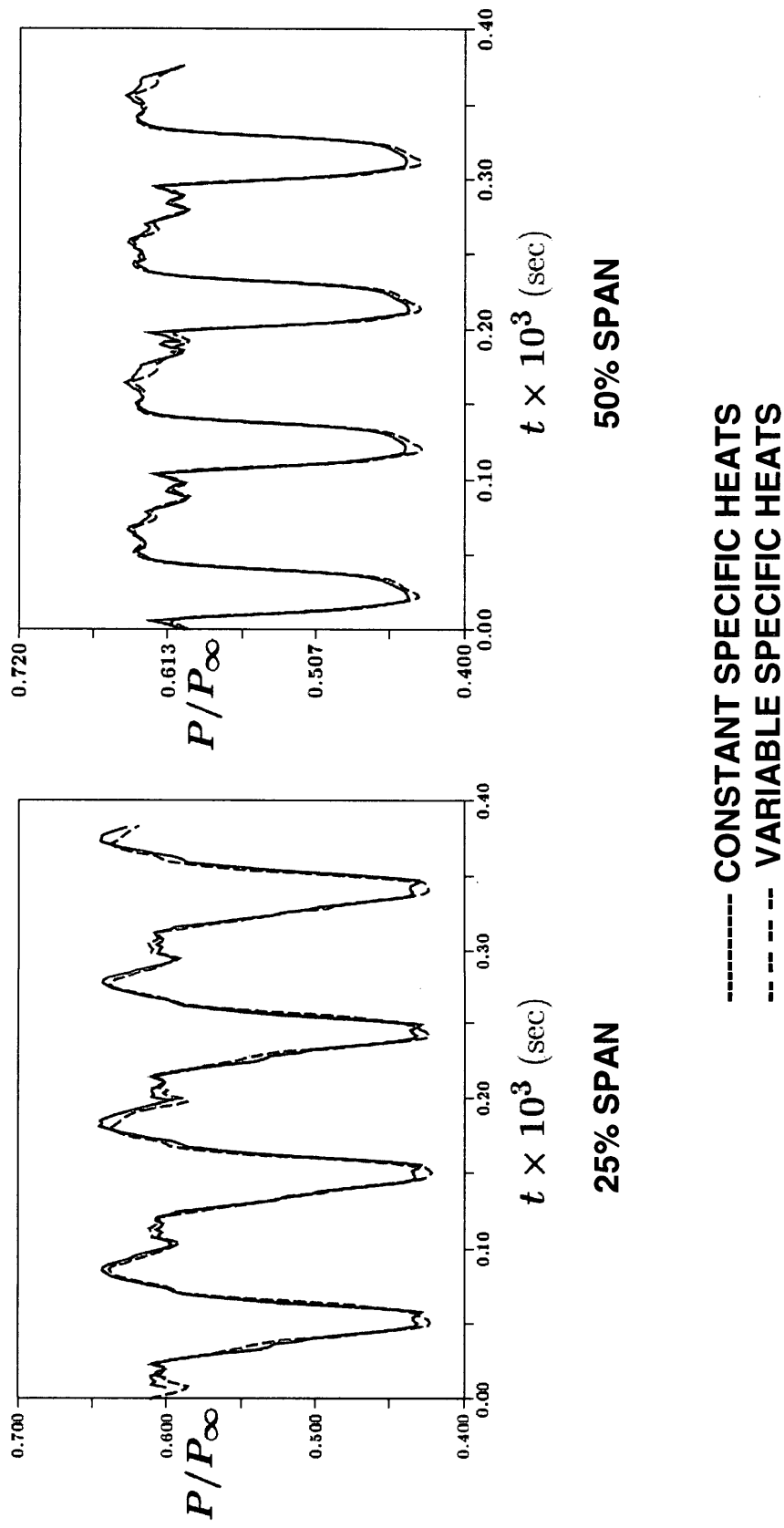
Instantaneous Entropy Function - Rotor Exit





Unsteady pressure – Rotor L.E.

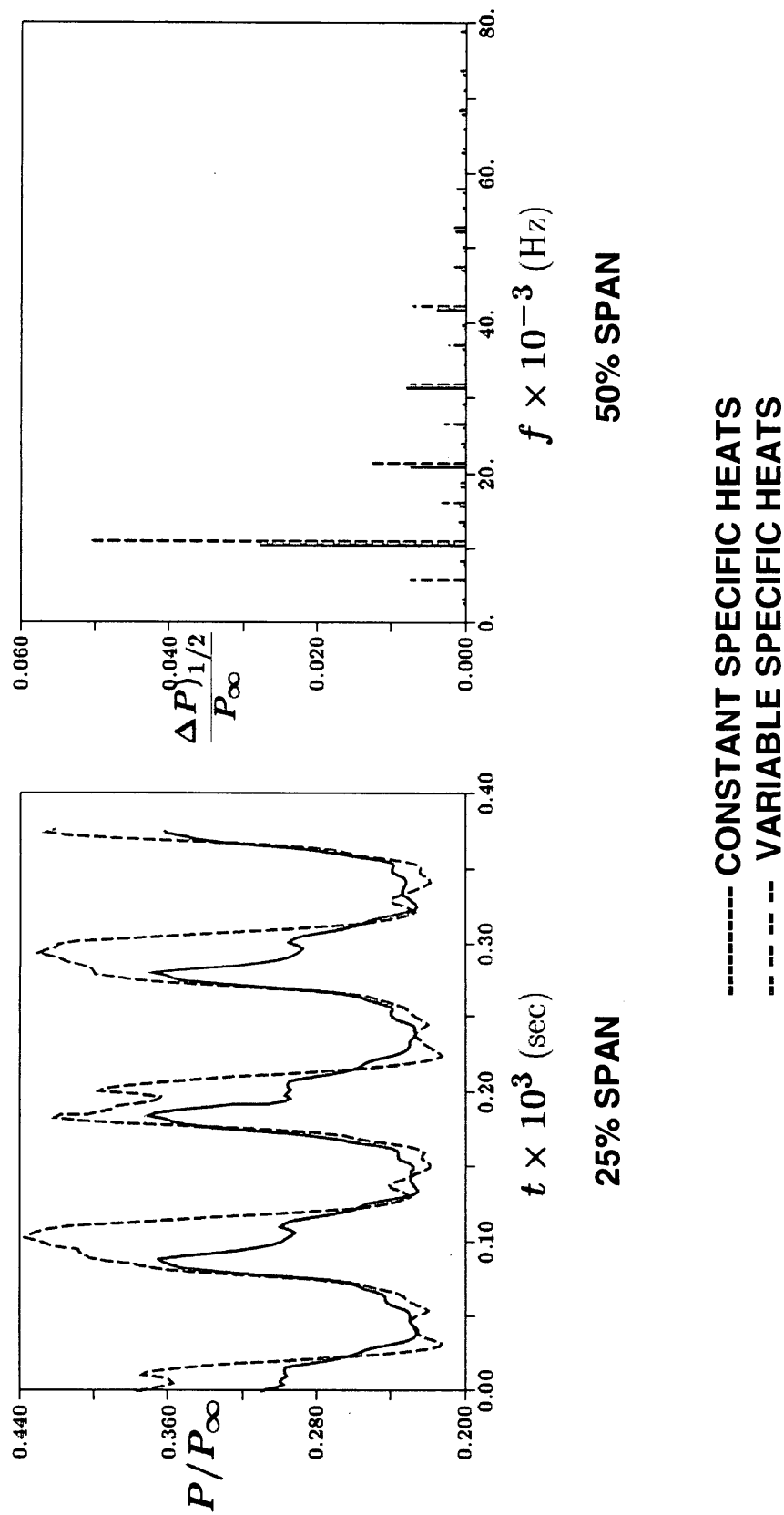
Time-averaged and unsteady pressures similar between 25% and 75% span





Unsteady pressure – Rotor L.E.

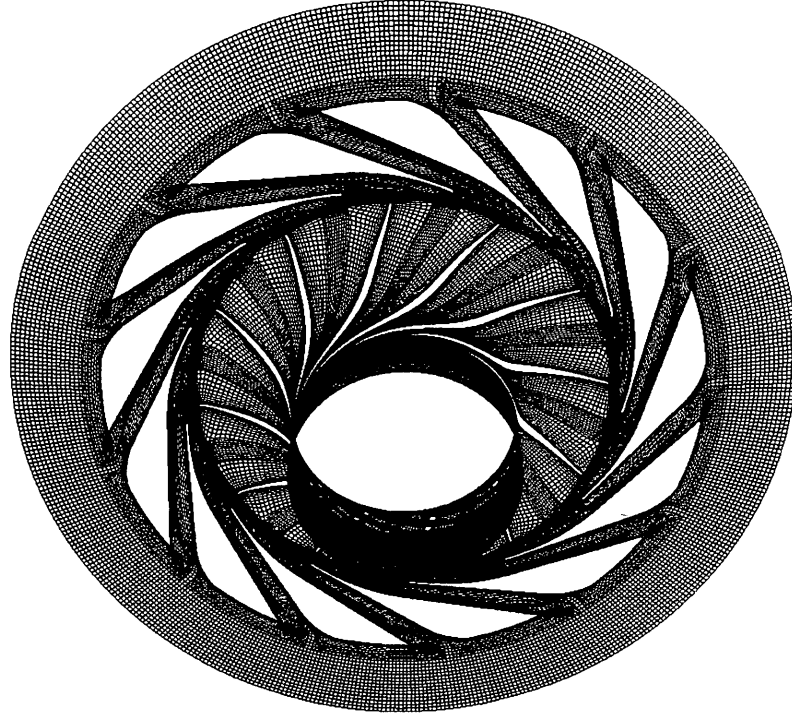
Time-averaged and unsteady pressures different in endwall regions



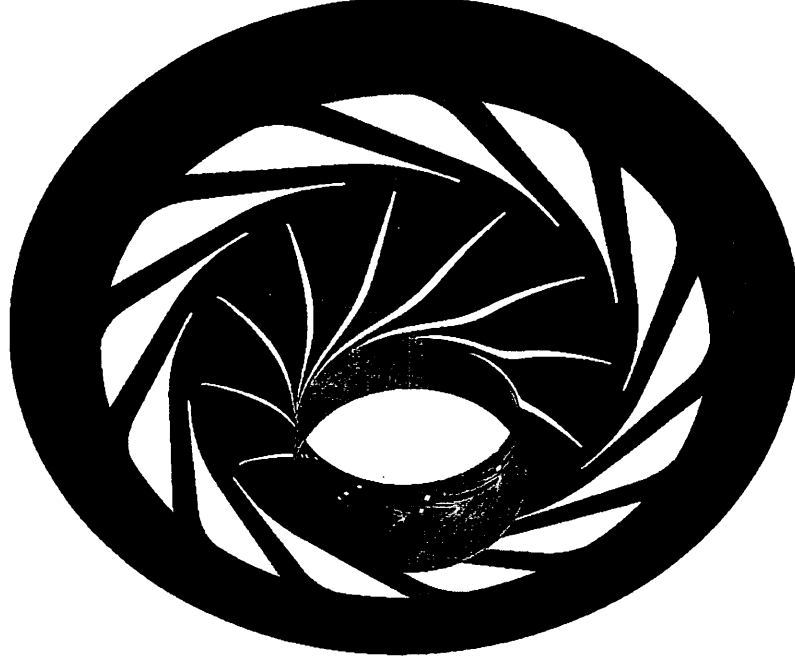


Pumps and Inducers

**Objective – Extend the code to pump and inducer geometries;
enable flange-to-flange predictions**



COMPUTATIONAL GRID

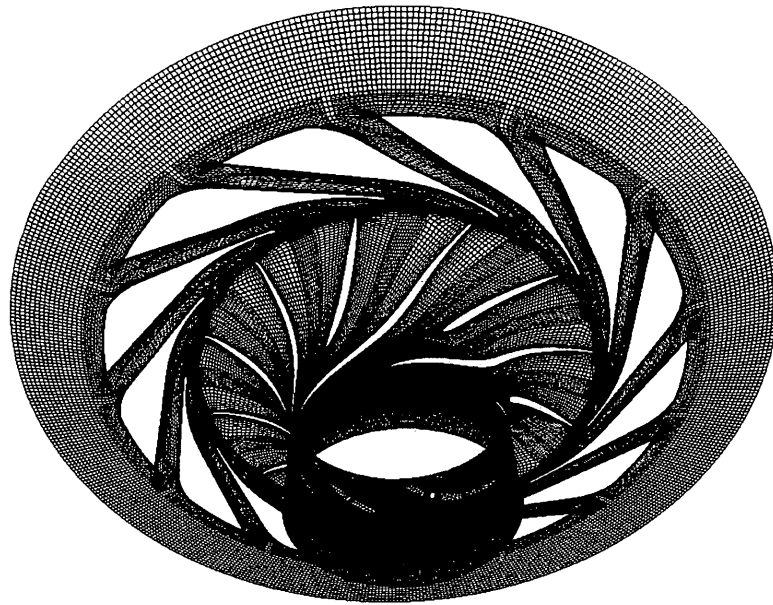


INSTANTANEOUS PRESSURE

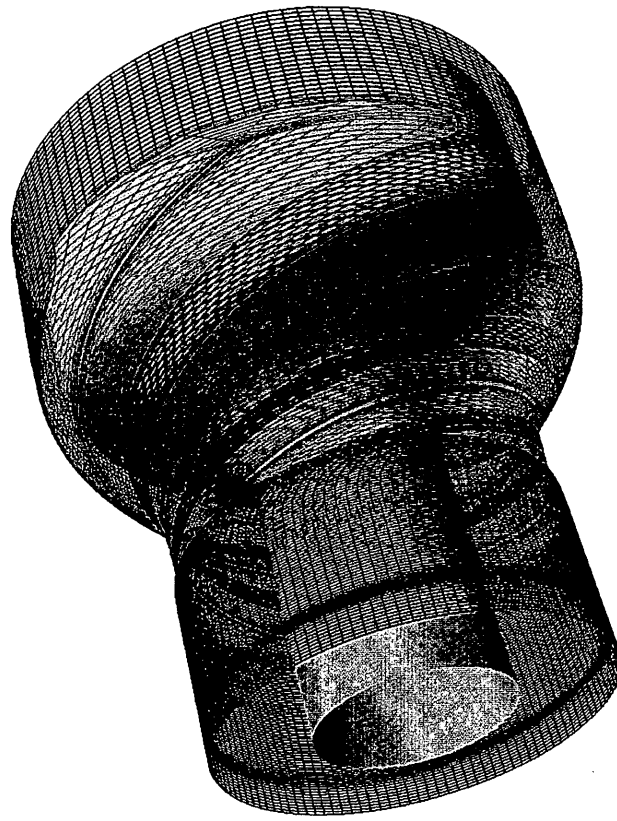


Pumps and Inducers

Simulations in Progress



IMPELLER W/SPLITTERS



INDUCER



Current Work and Future Plans

- **General fluid properties**
 - Reformulate equations without perfect gas assumption
 - Tabular fluid properties or compute based on equation of state
- **“All-speed” version of Corsair**
 - Sensors to switch between incompressible (pre-conditioning) and compressible physics
 - Dual time stepping for time accuracy
- **Two-phase flows**
- **Cavitation modeling**



SUPPLEMENTAL CHARTS



CORSAIR Validation - I

Test Case	Flow	Notes
UTRC LSRR Turbine (1 and 1.5-stage)	subsonic	Steady and unsteady pressure, wake data, exit traverse data, hot streak data, tip clearance data
Langston Cascade	subsonic	Steady pressure, loss distributions, flow angle distributions, Stanton No. distributions
PW F119 2-stage counter-rotating turbine	transonic	Steady and phase-resolved unsteady pressure, efficiency, film cooling
SSME 2-stage turbine	subsonic	Steady and phase-resolved unsteady pressure
GE LSRT 2-stage turbine	subsonic	Steady pressure data, phase-resolved unsteady momentum thickness and shape factor



CORSAIR Validation - II

Test Case	Flow	Notes
NASA CERTS single-stage turbine	high subsonic	Steady pressure data, exit traverse of flow angle, total pressure and total temperature
UTC Carrier centrifugal compressor	subsonic	Steady pressure data, surface flow visualization
NASA Ames NACA 0012 pitching airfoil	transonic	Lift, drag and moment histograms (blade vibration, plunging and pitching)
VKI cascade	subsonic	Steady and unsteady pressure data, Strouhal number (vortex shedding)



CORSAIR Validation - III

Test Case	Flow	Notes
ABLE boundary layer analysis	subsonic	Boundary layer thickness, momentum thickness, skin friction
Roberts' cascade; PAK-B cascade	subsonic	Steady pressure data (transition models)
Circular cylinder	subsonic	Flow visualization, time-averaged separation location
Flat plate	subsonic	Analytical (laminar) and empirical skin friction